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Weapon and Sighting System Compatibility Assessment for Prototype Maxillofacial Protection Devices

by Frank Morelli and William H. Harper

ARL-TR-6367 **March 2013**

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ARL-TR-6367 **March 2013**

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REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED (From - To)
March 2013	Final	January 2011–December 2011

4. TITLE AND SUBTITLE
Weapon and Sighting System Compatibility Assessment for Prototype Maxillofacial Protection Devices

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Frank Morelli and William H. Harper

5d. PROJECT NUMBER
HEaDS UP ATO

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Laboratory
ATTN: RDRL-HRS-B
Aberdeen Proving Ground, MD 21005-5425

8. PERFORMING ORGANIZATION REPORT NUMBER
ARL-TR-6367

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) designed maxillofacial protection system prototypes to address the growing trend of facial injuries suffered by Soldiers deployed to theaters of war. These systems are designed to attach to existing helmet systems such as the Advanced Combat Helmet (ACH) or Crewman Vehicular Combat Helmet (CVCH), or are integrated within novel helmet system designs. Among the concerns for eventual utilization are compatibility issues when Soldiers sight standard issue weapons in both dismounted and mounted operational scenarios. First-article prototypes were provided to the U.S. Army Research Laboratory to conduct a rapid assessment on the influence of maxillofacial protection on sighting of standard issue small arms and sighting systems organic to combat vehicles. System front and side spatial breadth were identified as critical factors negatively affecting function by changing the natural spatial interactions between head, face, eye, and sighting system, across several small arms firing postures and combat vehicle sighting interfaces.

15. SUBJECT TERMS
facial protection, helmets, shooting performance, sighting offset, human factors, small arms, vehicle optics

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Frank Morelli
Unclassified	Unclassified	Unclassified	UU	44	19b. TELEPHONE NUMBER (*Include area code*) 410-278-8824

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

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Acknowledgments

The authors wish to thank the Aberdeen Test Center Firepower and Automotive Directorates at Aberdeen Proving Ground, MD, for their professionalism and courtesy in granting access to weapons, sighting systems, and vehicles examined during this assessment. The authors also wish to thank the Soldiers assigned to the U.S. Army Research Laboratory (ARL) for their careful and candid assessment of each prototype system described herein, as well as ARL Human Research and Engineering Directorate Dismounted Warrior Branch members Patricia Burcham, Jim Faughn, Samson V. Ortega, Lucia Salvi, and Jennifer Swoboda and for their assistance in coordinating and executing this assessment.

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1. Background

The U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) has developed maxillofacial protection system prototypes to address the growing trend of facial injuries suffered by Soldiers deployed to theaters of war. These systems are designed to attach to existing helmet systems such as the Advanced Combat Helmet (ACH) or Combat Vehicle Crewman Helmet (CVCH), or are integrated within novel helmet system designs. Among the concerns for eventual utilization of such systems are compatibility issues that arise when Soldiers are asked to sight standard issue weapons in both dismounted and mounted operational scenarios. Five first-article prototypes were provided to the U.S. Army Research Laboratory (ARL) to conduct a rapid assessment on the influence of prototype maxillofacial protection systems on sighting of standard issue small arms and sighting systems organic to combat vehicles.

The technical report is organized into two sections. Part I of this report addresses compatibility issues with small arms weapon systems in common dismounted firing postures. Part II expands the assessment by addressing compatibility between the prototypes and sighting systems located within common combat vehicle platforms. A brief vehicle hatch visibility assessment is also included at the conclusion of Part II.

The dismounted component of this assessment focused on how well users were able to sight their weapon while wearing prototype maxillofacial protection systems. Weapon sighting compatibility interference from facial systems designed to increase survivability has been shown with Soldiers wearing chemical-biological protective mask systems, who took longer to engage targets when using iron sights vs. a close combat optic (CCO) sighting system relative to baseline conditions, where no protective mask systems were worn (Garrett et al., 2006). Likewise, Harper et al. (2011) revealed similar negative effects of accuracy as a function of cheek-to-stock displacement, which degraded as both range to target and cheek-to-stock offset increased. Functional sighting issues related to displacement caused by the maxillofacial prototypes were therefore a primary factor considered during the small arms sighting system compatibility assessment.

2. Methodology

Participants in the dismounted compatibility assessment were asked to rate the ease or difficulty of acquiring a target sight picture and predict the ease or difficulty of maintaining that sight picture over time, given the requisite effort exerted to acquire it and any accompanying head or

neck strain deemed necessary to maintain it. They were also asked to rate the quality of the sight picture they were able to acquire with each weapon, sighting system, and maxillofacial protection system configuration. Using an "area perceived" determination, participants rated a full sight picture as optimal and classified a partial sight picture subjectively based on the approximate percentage of the target visible during the sighting process. Three Soldiers stationed at Aberdeen Proving Ground and at the ARL's Adelphi Laboratory Center, MD, participated in this initial assessment, which was intentionally designed to be a qualitative appraisal of system design attributes on first article prototypes. This allowed designers to accelerate functional changes, at lower cost and with greater efficiency, based on feedback from the user community.

3. Instruments and Apparatus

3.1 Maxillofacial Protection System Prototypes

Five helmet-integrated and ACH/CVCH-attached maxillofacial protection system prototypes and a baseline system were evaluated during this assessment. They were categorized using the following designations, which were provided by NSRDEC:

1. CIPHER (Integrated headgear system).
2. INTERCPT (Integrated headgear system).
3. FASTBAC (ACH/CVCH-attached maxillofacial variants).
4. FIREBALL (ACH/CVCH-attached maxillofacial variants).
5. SMASHUP (ACH-attached maxillofacial variant).
6. Baseline – ACH and CVCH without adorned maxillofacial protection system.

The systems, pictured in figures 1–5 were supplied as part of a demonstration maxillofacial protection prototype development effort led by NSRDEC and supported by human factors and ergonomics analysis provided by the ARL Human Research and Engineering Directorate's Dismounted Warrior Branch.

Figure 1. CIPHER (Integrated helmet system).

Figure 2. INTERCPT (Integrated helmet system).

Figure 3. FASTBAC (attached to ACH).

Figure 4. FIREBALL (attached to ACH).

Figure 5. SMASHUP (attached to ACH).

3.2 Weapons and Weapon Sighting Systems

Two small arms weapon systems were employed in this assessment: the M4 carbine and the M240B medium machine gun. The following weapon sighting systems were attached to the M4 carbine and evaluated for compatibility with all maxillofacial protection configurations: the M68 CCO, M150 Advanced Combat Optical Gunsight (ACOG), and the light thermal weapon sight (LTWS). For the M240B medium machine gun, the M145 machine gun optic (MGO) and medium thermal weapon sight (MTWS) were used to evaluate maxillofacial protection compatibility. These sighting systems are military standard issue and in common use among military personnel. For an overview of sighting systems, their properties and major distinctions with respect to function, see Army Test and Evaluation Center Test Operations Procedure (ATEC TOP) 3-3-116 (1972).

4. Procedures

Each participant was asked to evaluate each prototype maxillofacial protection system for ease of donning/doffing, comfort, utility of cheek/shoulder-to-stock positioning (for small arms systems), ability to acquire and maintain a target sight picture, and to correctly aim the weapon. Participants evaluated these factors for each weapon, sighting system and maxillofacial protection system combination. A delineation of the conditions examined is included in table 1.

Table 1. Weapon, sighting system, and maxillofacial protection system configuration combinations.

Weapons	**Sights**	**Maxillofacial Protection Systems**
M4	M68 CCO	CIPHER
M240B	M150 ACOG	INTERCPT
—	M145 MGO	FASTBAC
—	LTWS	FIREBALL
—	MTWS	SMASHUP
Combinations		
CIPHER-M4-M68	**INTERCPT**-M4-M68	**FASTBAC**-M4-M68
CIPHER-M4-ACOG	**INTERCPT**-M4-ACOG	**FASTBAC**-M4-ACOG
CIPHER-M4-LTWS	**INTERCPT**-M4-LTWS	**FASTBAC**-M4-LTWS
CIPHER-M240B-M145	**INTERCPT**-M240B-M145	**FASTBAC**-M240B-M145
CIPHER-M240B-MTWS	**INTERCPT**-M240B-MTWS	**FASTBAC**-M240B-MTWS
FIREBALL-M4-M68	**SMASHUP**-M4-M68	—
FIREBALL-M4-ACOG	**SMASHUP**-M4-ACOG	—
FIREBALL-M4-LTWS	**SMASHUP**-M4-LTWS	—
FIREBALL-M240B-M145	**SMASHUP**-M240B-M145	—
FIREBALL-M240B-MTWS	**SMASHUP**-M240B-MTWS	—

Tharion and Obusek (2000) showed that prototype battlefield equipment caused poor sighting capability and resultant negative effects upon marksmanship accuracy, dispersion, and timing characteristics due to the interaction of equipment and firing posture. Based on such known effects, the M4 carbine was evaluated in both the standing and prone positions while the M240B, given its weight characteristics and handling dynamics, was only evaluated in the prone firing position.

5. Data Analysis

This initial assessment was intended as an early stage prototype development effort designed to gather subjective compatibility estimations from experienced Soldiers and human factors professionals regarding the prototype maxillofacial protection systems provided by NSRDEC. Only subjective ratings, fit preferences, and recommendations for improvement expressed by the Soldiers and researchers who participated were recorded. This information was intended to guide design with due consideration for small arms operational sighting dynamics at the beginning stages of prototype development.

6. Results

For reference, a summary of the results detailed in this section is provided in figure 6, with maxillofacial protection system, sighting system, weapon system, and firing posture conditions shown relative to the success reported in obtaining/maintaining a sight picture.

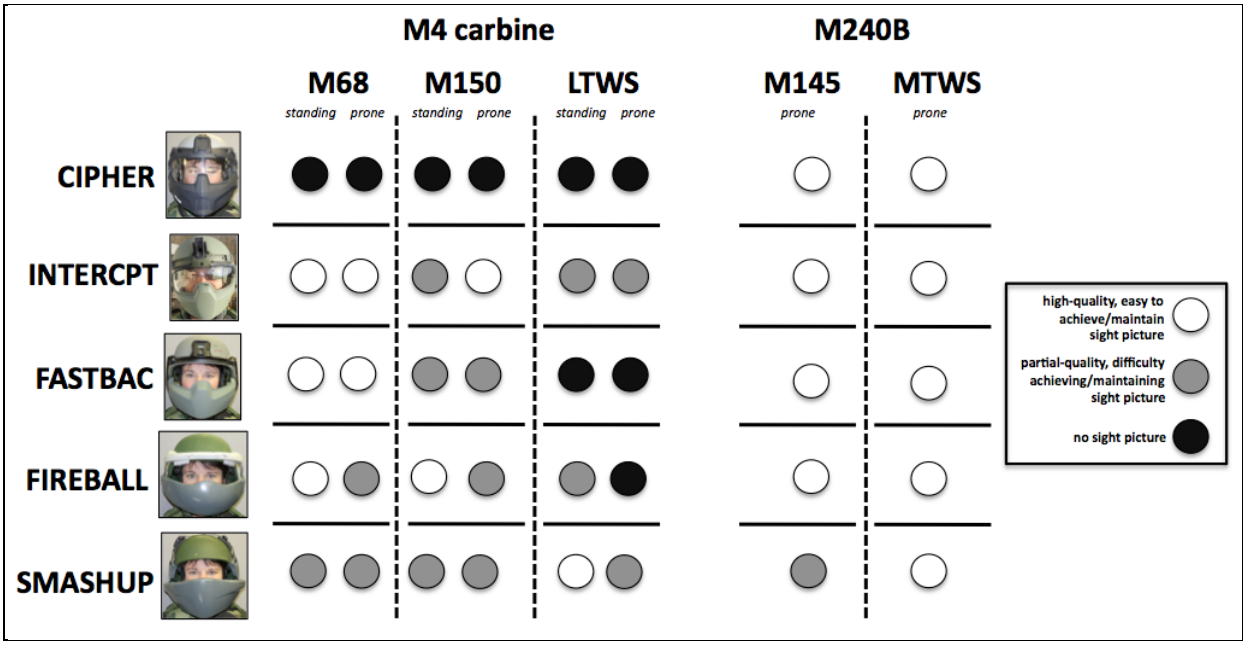

Figure 6. Graphical results summary of reported sight picture acquisition by maxillofacial protection system, sighting system, weapon system, and firing posture conditions.

6.1 CIPHER: M4 Weapon Compatibility

When in the standing posture, all three Soldiers were unable to obtain a proper sight picture for any of the weapon sights. As can be seen in figure 7 (right image), the CIPHER system visor and mandible guard displaces the shooter's face so far off the stock that using the M4 in a standing posture was not possible with any of the sighting systems. Generally, sighting offset causes optical distortions, with implications for performance and resultant eyestrain. Zeroing under conditions of misalignment has also proven detrimental to performance (Redden et al., 2006).

Figure 7. CIPHER, M4 carbine, prone/standing postures.

In the prone firing position, Soldiers also exhibited difficulty in obtaining a proper sight picture while wearing the CIPHER system (figure 8). Two of three Soldier participants were unable to obtain a proper sight picture across all sighting systems. As can be seen in the CIPHER prone images, the helmet system pushed the cheek and eye position so far off the stock of the weapon that it forced shooters into awkward head and neck positions in an attempt to obtain a sight picture, which ultimately remained a very difficult to impossible undertaking.

Figure 8. CIPHER, M4 carbine, prone posture.

6.2 CIPHER: M240B Weapon Compatibility

When sighting the M240B in the prone firing position with the M145 MGO, Soldiers generally had little to no problem obtaining or maintaining a good sight picture. The CIPHER system's structural features did not obstruct line-of-sight alignment between the head and optic, given that the eye relief required for proper sighting accommodated the CIPHER system frontal form factor. This distance was below the required threshold for properly sighting the MGO, which is among the more forgiving sighting systems with respect to allowable eye-to-optic standoff.

When using the MTWS, two Soldiers were able to acquire a full sight picture from a natural (i.e., comfortable) firing position. The remaining Soldier had difficulty obtaining a proper sight picture due to extreme head tilt and accompanying neck strain. The curved shape of the top portion of the M240B buttstock (highlighted in figure 9, right image) accommodates the side dimensions of the CIPHER system quite well, generally allowing Soldiers to achieve proper eye alignment behind the sights of the M240B.

Figure 9. CIPHER, M240B, prone posture.

6.3 INTERCPT: M4 Weapon Compatibility

When in the standing posture, there was considerable difficulty in obtaining and maintaining a sight picture when using the M150 optic. Soldiers had to push the INTERCPT system into the buttstock with considerable force in an attempt to achieve a sight picture, resulting in severe head tilt and neck strain. This resulted in a partial sight picture at best for two Soldiers, with the remaining Soldier unable to achieve a sight picture at all (figure 10).

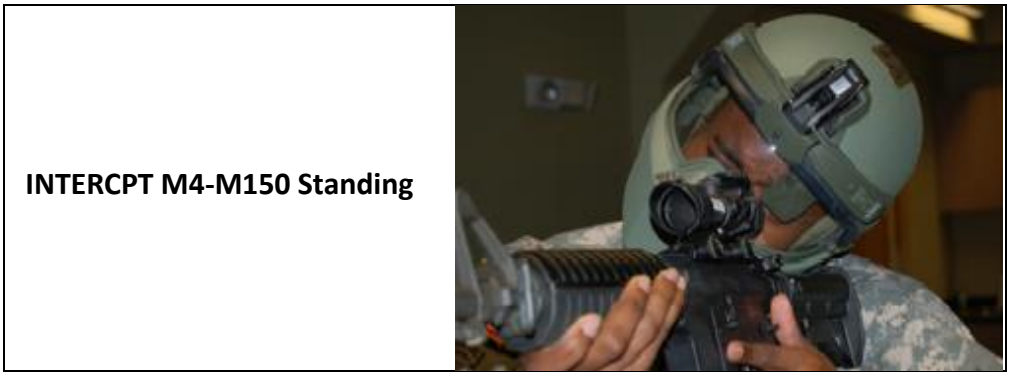

Figure 10. INTERCPT, M4 carbine, standing posture.

When using the M68 sight, obtaining a sight picture was more feasible relative to the M150 in a standing posture, but remained quite difficult to achieve and required severe head tilt, making the sight picture difficult to maintain (figure 11).

Figure 11. INTERCPT, M4 carbine, standing posture.

Using the M4 with LTWS made it very difficult to impossible to obtain a sight picture, in either the standing or prone firing positions. Achieving a sight picture required tilting the head to an angle approaching 45°. When Soldiers positioned their head naturally using the LTWS (as shown in figure 12), they generally could not achieve a full target sight picture.

Figure 12. INTERCPT, M4 carbine, prone posture.

When in the prone firing position and using the M150 sight, there was some difficulty in acquiring the sight picture. However, once Soldiers were able to acquire a sight picture, they stated that maintaining it was feasible with some head tilt, which caused only mild accompanying neck strain (figure 13).

Figure 13. INTERCPT, M4 carbine, prone posture.

When using the M68 sight, Soldiers were generally able to acquire a full sight picture in both the standing and prone firing positions, but this was only achievable when pushing the face shield into the buttstock with some force and canting the weapon. This resulted in discomfort, and also caused the buttstock itself to shift from natural shouldering to an unnatural position of less stability at the edges of the shoulder (figure 14).

Figure 14. INTERCPT, M4 carbine, prone posture.

6.4 INTERCPT: M240B Weapon Compatibility

When in the prone firing position and using the M145 MGO, two Soldiers were able to achieve and maintain a partial sight picture without much associated head/neck tilt or related discomfort (figure 15).

Figure 15. INTERCPT, M240B, prone posture.

The remaining Soldier was unable to achieve a sight picture due to obstruction and resultant cheek-to-stock standoff caused by the side of the INTERCPT system. This forced a relatively severe neck tilt angle in an unsuccessful attempt to sight the weapon (figure 16).

Figure 16. INTERCPT, M240B, prone posture.

When using the MTWS, all Soldiers were able to acquire a full sight picture from a natural (i.e., comfortable) firing position without difficulty, though one Soldier noted that to maintain the sight picture would require pushing the front brim of the INTERCPT system rather than the eye and front cheek region against the MTWS's rubberized eyecup. Despite this, a steady firing posture that could reliably be maintained over time was achieved. As noted for the CIPHER system, the curved shape of the top portion of the M240B buttstock accommodates the side dimensions of the INTRCPT system well, allowing for proper eye alignment and relatively natural firing posture behind the sights of the M240B (figure 17).

Figure 17. INTERCPT, M240B, prone posture.

6.5 FASTBAC: M4 Weapon Compatibility

When in the standing posture, there was some difficulty in obtaining and maintaining a sight picture when using the M150 sight. This was due to eye-optic offset in excess of the allowable distance threshold, caused by interference from the sides of the maxillofacial protection system as the Soldier attempted to cheek the weapon (figure 18).

Figure 18. FASTBAC, M4 carbine, standing posture.

When using the M68 sight, obtaining a sight picture was easier relative to the M150. Less head and neck tilt was required, and there was less interference from the side of the maxillofacial protection system to achieve the required eye-optic alignment as Soldiers cheeked the weapon (figure 19).

Figure 19. FASTBAC, M4 carbine, standing posture.

When using the LTWS, Soldiers found it very difficult to impossible to obtain a sight picture due to interference between the helmet brim, the sides of the maxillofacial protection system, and the weapon buttstock, all of which prevented the linear depression of the rubberized eyecup required to activate the sight (figure 20).

Figure 20. FASTBAC, M4 carbine, standing posture.

When in the prone firing position and using the M150 sight, Soldiers expressed difficulty in acquiring and maintaining a sight picture due to severe head tilt and the accompanying neck strain required (figure 21).

Figure 21. FASTBAC, M4 carbine, prone posture.

Relative to the M150, sighting the M68 optic was more straightforward, requiring less head tilt and a lesser degree of accompanying neck strain in order to achieve a sight picture (figure 22).

Figure 22. FASTBAC, M4 carbine, prone posture.

Soldiers were unable to acquire a sight picture when using the LTWS. They expressed considerable difficulty when attempting to depress the eyecup due to interference between the brim of the helmet and the front of the maxillofacial protection system (shown clearly in figure 23). Linear depression of the rubberized eyecup as it coupled flush with the eye socket and face was unachievable, thereby rendering the sight inactive.

Figure 23. FASTBAC, M4 carbine, prone posture.

6.6 FASTBAC: M240B Weapon Compatibility

When in the prone firing position and using both the M145 MGO and the MTWS, Soldiers generally found it fairly easy to achieve a full sight picture. Sighting the weapon with both optics did not require much head tilt or accompanying neck strain, resulting in a high quality sight picture that was relatively easy to maintain (figure 24).

Figure 24. FASTBAC, M240B, prone posture.

6.7 FIREBALL: M4 Weapon Compatibility

While wearing the FIREBALL system in the standing firing position and sighting the M68 and M150 optics, all Soldiers were able to attain a proper sight picture by firmly pressing the facial protection system against the side of the buttstock to shift the helmet (see figure 25). However, this posture caused considerable neck strain and head discomfort, and Soldiers felt that it would be very difficult to maintain the sight picture over time. When using the LTWS, two Soldiers were unable to achieve a sight picture. The remaining Soldier was able to achieve a sight picture by pressing the system against the stock of the weapon to shift the helmet on the head, but as with the M68 and M150 optics, felt that it would be difficult to maintain this sight picture over time due to the discomfort caused by this posture.

Figure 25. FIREBALL, M4 carbine, standing posture.

Wearing the FIREBALL system in the prone firing position and using the M150 sight, two of the Soldiers were unable to attain a proper sight picture. For these Soldiers, interference caused by the side of the FIREBALL system did not allow for the linear alignment required between eye and optic for proper sighting, even when attempting to press the system against the side of the buttstock as was described for the standing position under this configuration (figure 26, right image). The remaining Soldier was able to achieve a sight picture, but did not feel that maintaining it over time was a reasonable expectation given the extreme head tilt required, coupled with accompanying neck muscle strain. When using the M68 sight, all Soldiers were able to achieve at least a partial sight picture, but felt that it would be difficult to maintain it over time due to the neck tilt and strain required (figure 26, center). When using the LTWS, all three Soldiers had tremendous difficulty and were not able to achieve a sight picture due to interference between the rubberized eyecup, the helmet attachment mechanism (shown in white against the olive drab background of the helmet, figure 26, left image), and the front of the FIREBALL system.

Figure 26. FIREBALL, M4 carbine, prone posture.

6.8 FIREBALL: M240B Weapon Compatibility

While wearing the FIREBALL system in the prone firing position, two Soldiers were able to achieve a full sight picture without difficulty using the M145 MGO. The remaining Soldier was also able to achieve a full sight picture, but reported difficulty acquiring and maintaining it due to the amount of head tilt and accompanying neck muscle strain associated with the sighting posture. When using the MTWS, two Soldiers were able to achieve a full sight picture without difficulty given the space between the FIREBALL system and the brim of the helmet, which easily accommodated the rubberized eyecup on the sight. The remaining Soldier was able to achieve a full sight picture, but found it difficult to maintain over time due to the degree of head tilt required (figure 27).

Figure 27. FIREBALL, M240B, prone posture.

6.9 SMASHUP: M4 Weapon Compatibility

When wearing the SMASHUP system in the standing posture, there was some difficulty obtaining and maintaining a sight picture when using the M150 sight. All Soldiers found it difficult to shoulder and cheek the weapon naturally given the wide breadth of the SMASHUP system. Two were able to achieve a sight picture but reported severe head tilt and associated

neck strain, negatively influencing the ability to maintain the posture over time. A technique used by one Soldier to achieve target sight picture was to rest the side of the buttstock upon the upper "ledge" surface of the side of the SMASHUP system (images at center and right, figure 28). The remaining Soldier was unable to achieve a sight picture at all with the SMASHUP system, commenting that the form factor width was too extreme to allow for sighting with the M150. When using the M68 optic, all Soldiers were able to obtain a sight picture, but the severe degree of head tilt angle required caused them difficulty in maintaining the posture. When using the LTWS, all three Soldiers were able to achieve a full sight picture without difficulty given the accommodating space between helmet brim and SMASHUP system front, where the rubberized eyecup was easily inserted and depressed.

Figure 28. SMASHUP, M4 carbine, standing posture.

When in the prone firing position and using the M150 sight, there was some difficulty in acquiring and maintaining sight picture, with Soldiers commenting that the buttstock was forced from a natural, stable shoulder position toward an unstable position at the upper arm. When using the M68 sight, Soldiers had less trouble and reported less neck strain when attempting to maintain the sight picture relative to the M150 optic, but the posture nonetheless required significant head tilt and caused discomfort. When using the LTWS, one Soldier was unable to achieve a sight picture due to the severe head tilt and weapon cant required, with the two remaining Soldiers reporting difficulty in maintaining the sight picture they achieved due to the severe head tilt and weapon cant required (figure 29).

Figure 29. SMASHUP, M4 carbine, prone posture.

6.10 SMASHUP: M240B Weapon Compatibility

When in the prone firing position and using the M145 MGO, Soldiers generally found it difficult to achieve a full sight picture due to obstruction from the surface beneath the SMASHUP system's side "ledge," which prevented the buttstock from being adjusted easily along a vertical plane when attempting to sight the weapon (see image at left, figure 30). Nonetheless, two Soldiers were able to achieve a partial sight picture, with the third achieving a full sight picture albeit with considerable difficulty. When using the MTWS, Soldiers were able to achieve a full sight picture without difficulty due to the generous space between SMASHUP system front and helmet brim (right image, figure 30).

Figure 30. SMASHUP, M240B, prone posture.

6.11 Part II – Vehicle Sighting System Compatibility Assessment

The mounted component of this assessment focused on how well users were able to employ the sighting systems found in two combat vehicles: variants of the Stryker and Bradley Fighting Vehicle. A human factors analyst:

1. rated the ease or difficulty of acquiring a target sight picture while wearing prototype maxillofacial protection systems,
2. predicted the ease or difficulty of maintaining that sight picture over time, and
3. rated the quality of the sight picture, if obtainable, while wearing each maxillofacial protection system configuration.

7. Methodology

As in the dismounted assessment, the analyst employed an "area perceived" determination, rating a full sight picture as optimal and classifying a partial sight picture subjectively based on the percentage of the target visible during the sighting process. The analyst wore a CVCH with

integrated maxillofacial protection systems and the complete integrated system for those that included their own helmet component. In a comprehensive review of the effects of chemical protection systems on performance, Krueger (1997) notes that armor/aviator masks prevent proper vehicle system optic sighting due to the requirement to apply pressure forward against the optic and the offset caused by the mask that prevents it. Based in part on this finding, the analyst attempted to sight the optics in conditions both with and without the facial protection component (i.e., the analyst sighted using the helmet and hard-mounted bracket alone, and also attempted to sight using the helmet, hard-mounted bracket, and adorned maxillofacial protection system) for systems that featured hard-mounted attachment brackets for the CVCH. The analyst attempted to achieve a target sight picture using each vehicle's three main sighting systems: the gunner's primary sight (GPS), gunner's thermal sight (GTS) and gunner's auxiliary sight (GAS).

Additionally, human factors practitioners examined the potential for visibility degradation while wearing the prototype systems and attempting to egress from vehicle hatches. This assessment also included a third vehicle, the M1A1/M1A2 Abrams tank. As in the dismounted assessment, this effort was intentionally designed to be a qualitative appraisal of system design attributes on first article prototypes, specifically regarding their compatibility with common vehicle sighting systems and hatch openings, allowing designers to quickly implement functional changes based on the human factors feedback provided.

7.1 Sighting System Compatibility – Stryker Combat Vehicle

7.1.1 CVCH, FIREBALL Helmet Bracket, No Maxillofacial Protection (figure 31)

GPS and **GAS** - CVCH bracket had no impact. While the bracket is close to making contact just above the GPS, there is no actual interference. Sight picture was achieved without difficulty.

GTS - Sight picture was achieved without difficulty.

Figure 31. FIREBALL bracket only (STRYKER vehicle).

7.1.2 CVCH, FIREBALL Helmet Bracket With Maxillofacial Protection (figure 32)

GPS and **GAS** - Sight picture was not achieved. FIREBALL system with maxillofacial protection caused the observer's head to be positioned beyond threshold standoff distance for both sighting systems.

GTS - Sight picture was achieved without difficulty.

Figure 32. FIREBALL bracket and maxillofacial protection (STRYKER vehicle).

7.1.3 CVCH, FASTBAC Helmet Bracket, No Maxillofacial Protection (figure 33)

GPS, GTS and **GAS** - CVCH bracket had no impact and was lower profile than the bracket featured on the FIREBALL system, a positive aspect given that increased standoff from combat vehicle sighting systems decreases the likelihood of visualizing a target sight picture.

Figure 33. FASTBAC, bracket only (STRYKER vehicle).

7.1.4 CVCH, FASTBAC Helmet Bracket With Maxillofacial Protection (figure 34)

GPS and **GAS** - Sight picture was not achieved. FASTBAC system with maxillofacial protection caused interference, forcing the observer's head to be positioned beyond threshold standoff distance for both sighting systems.

GTS - Sight picture was achieved without difficulty.

Figure 34. FASTBAC bracket and maxillofacial protection (STRYKER vehicle).

7.1.5 INTERCPT, No Maxillofacial Protection (figure 35)

GPS - Partial sight picture achieved, with roughly 20% of the optimal field of view (FOV) visible. However, tilting the helmet backward improved the visible FOV to roughly 80%. The prototype heads-up display (HUD) device that hangs down from the helmet also interferes with the brow pad on the GPS (image at left, below), increasing standoff from the sighting system.

GTS - Sight picture was achieved without difficulty.

GAS - Sight picture was not achieved without tilting the helmet. When tilting the helmet backward, a nearly full FOV was achieved, albeit with some interference between the HUD and brow pad. This was consistent with the interference experienced when sighting the GPS.

Figure 35. INTERCPT helmet only (STRYKER vehicle).

7.1.6 INTERCPT with Maxillofacial Protection (figure 36)

GPS - Partial sight picture was achieved, with roughly 20% of the optimal FOV visible.

GTS - Sight picture was achieved without difficulty.

GAS - Sight picture was not achieved. INTERCPT system with maxillofacial protection caused the observer's head to be positioned beyond sighting threshold standoff distance.

Figure 36. INTERCPT bracket and maxillofacial protection (STRYKER vehicle).

7.1.7 CIPHER, Maxillofacial Protection With Visor (figure 37)

GPS - Partial sight picture achieved, with roughly 20% of the optimal FOV visible.

GTS - Sight picture was achieved without difficulty.

GAS - Sight picture not achieved. CIPHER system with maxillofacial protection and visor caused the observer's head to be positioned beyond sighting threshold standoff distance.

Figure 37. CIPHER with maxillofacial protection and visor (STRYKER vehicle).

7.1.8 CIPHER, No Maxillofacial Protection, No Visor (figure 38)

GPS - Partial sight picture achieved, with roughly 40% –50% of the optimal FOV visible. Tilting the helmet backward improved sighting to full FOV.

GTS - Sight picture was achieved without difficulty.

GAS - Partial sight picture achieved, with roughly 10% of the optimal FOV visible. Tilting the helmet backward improved sighting to full FOV.

Figure 38. CIPHER, helmet only (STRYKER vehicle).

7.2 Sighting System Compatibility – Bradley Fighting Vehicle (BFV)

7.2.1 FASTBAC, No Maxillofacial Protection (figure 39)

GPS - Partial sight picture achieved, with roughly 40% of the optimal FOV visible. Tilting the helmet backward improved sighting to full FOV.

GTS - Sight picture was achieved without difficulty.

GAS - Full FOV was achieved straightaway without tilting the helmet backward.

Figure 39. FASTBAC, bracket only (BFV).

7.2.2 FASTBAC With Maxillofacial Protection (figure 40)

GPS - Partial sight picture achieved, with only 5% of the optimal FOV visible.

GTS - Sight picture was achieved without difficulty.

GAS - Sight picture was achieved without difficulty.

Figure 40. FASTBAC bracket and maxillofacial protection (BFV).

7.2.3 FIREBALL, No Maxillofacial Protection (figure 41)

GPS - Partial sight picture achieved, with roughly 60% of the optimal FOV visible. Full FOV was visible when tilting the helmet.

GTS - Sight picture was achieved without difficulty.

GAS - Sight picture was achieved without difficulty.

Figure 41. FIREBALL bracket only (BFV).

7.2.4 FIREBALL With Maxillofacial Protection (figure 42)

The FIREBALL maxillofacial protection system fit is tight when attached to the CVCH, producing excess compression on the ear cups, and causing discomfort for the user's ears.

GPS - Partial sight picture achieved, with roughly 10% of the optimal FOV visible.

GTS - Sight picture was achieved without difficulty.

GAS - Sight picture was unattainable. For both the GPS and the GAS, maxillofacial protection system components interfered with the brow pad on the sights, causing the observer's head to be positioned beyond sighting threshold standoff distance.

Figure 42. FIREBALL bracket and maxillofacial protection (BFV).

7.2.5 INTERCPT With Maxillofacial Protection (figure 43)

GPS - Partial sight picture achieved, with roughly 50% of the optimal FOV visible.

GTS - Sight picture was achieved without difficulty.

GAS - Sight picture was achieved without difficulty.

Figure 43. INTERCPT with maxillofacial protection (BFV).

7.2.6 INTERCPT, No Maxillofacial Protection (figure 44)

GPS - Partial sight picture achieved, with roughly 50% of the optimal FOV visible. The prototype HUD device hanging from the helmet interfered with the brow pad on the GPS, increasing standoff from the sighting system. However, tilting the helmet backward improved sighting to roughly 90% FOV and largely cleared the HUD obstruction.

GTS - Sight picture was achieved without difficulty.

GAS - Full FOV was achieved straightaway without tilting the helmet backward.

Figure 44. INTERCPT, helmet only (BFV).

7.2.7 CIPHER, Maxillofacial Protection With Visor (figure 45)

GPS - Partial sight picture achieved, with roughly 40% of the optimal FOV visible.

GTS - Sight picture was achieved without difficulty.

GAS - Sight picture not achieved. CIPHER system with maxillofacial protection and visor caused the observer's head to be positioned beyond sighting threshold standoff distance.

Figure 45. CIPHER with maxillofacial protection and visor (BFV).

7.2.8 CIPHER, Maxillofacial Protection, No Visor (figure 46)

GPS - Partial sight picture achieved, with roughly 40% of the optimal FOV visible.

GTS - Sight picture was achieved without difficulty.

GAS - Sight picture was achieved without difficulty.

Figure 46. CIPHER with maxillofacial protection, no visor (BFV).

7.2.9 CIPHER, No Maxillofacial Protection, No Visor (figure 47)

GPS - Partial sight picture achieved, with roughly 40% of the optimal FOV visible. Tilting the helmet allowed for a full FOV sight picture, but forced the helmet to impact the back of neck, causing considerable pain and discomfort.

GTS - Sight picture was achieved without difficulty.

GAS - Sight picture was achieved without difficulty.

Figure 47. CIPHER, helmet only (BFV).

7.2.10 Commander, Driver, and Gunner Position Visibility and Ingress/Egress Compatibility: CVCH With FASTBAC and FIREBALL Maxillofacial Protection

In addition to examining system compatibility with the optics and sights featured on vehicle systems, the FASTBAC and FIREBALL maxillofacial protection systems were evaluated for potential visibility degradation relative to the environment surrounding the vehicle and internal vehicle displays, as well as potential visibility degradation when attempting to ingress or egress the vehicle through rooftop hatches. Three vehicles were examined: the Stryker M1128 Mobile Gun System (MGS), the M1A1/M1A2 Abrams tank, and the BFV.

7.2.11 External Visibility

From the perspective of the driver, visibility was generally unaffected by either the FASTBAC or the FIREBALL maxillofacial protection systems on the vehicles that were assessed. Visibility was examined with the driver's hatch open, and while closed and viewing the outside environment through the driver's vision blocks. With the hatch closed, external visibility was unaffected and all internal vehicle displays were visible while wearing both the FASTBAC and the FIREBALL systems. With the driver's hatch open, no degradation was reported relative to wearing the CVCH alone for the Stryker MGS and both the M1A1 and M1A2 Abrams tanks. However, wearing the FIREBALL negatively affected distance vision with the driver's hatch open in the BFV, causing the operator to tilt the head back in order to see distant objects. This was caused primarily by the limited visibility afforded to the observer by the available open space between the edge of the CVCH at the forehead and the upper front edge of the FIREBALL facial protection device.

7.2.12 Ingress/Egress

Wearing the CVCH with the FASTBAC maxillofacial protection system forced the user to tilt the head lower than when no maxillofacial system was employed during ingress and egress maneuvers. This was necessary for visibility of hand and foot positioning during ingress, egress, and for navigation across the top surface of the vehicle during mounting/dismounting. Given the FIREBALL system's more restricted vertical field of view (essentially a more narrow available viewing space between the front edge of the CVCH and the top front edge of the FIREBALL maxillofacial system), using the CVCH with the FIREBALL maxillofacial protection device exacerbated this effect, requiring the operator to tilt the head down at more oblique angles relative to wearing the FASTBAC (an example of this effect is shown in figure 48).

Figure 48. Operator ingress/egress visibility head position adaptations.

Rotating the head along the horizontal plane, visibility was not influenced while wearing either the FASTBAC or FIREBALL system and was determined to be no different than when wearing the CVCH alone.

7.2.13 Mandible Attachment Issues

Note that the FIREBALL system was more difficult to attach once the CVCH was on the user's head. Orienting the maxillofacial protection system to attach it required two individuals in order to achieve proper alignment for snapping the system into the bracket, which is hard-mounted to the CVCH. Snapping the maxillofacial protection device into the CVCH mounted bracket before putting on the helmet was also difficult since the FIREBALL maxillofacial system compresses the ear cups on the CVCH, rendering the available opening too narrow to comfortably place on the user's head. This was not the case with the FASTBAC system, which easily attached to the CVCH-mounted bracket without compressing the ear cups, resulting in no difficulty when donning the CVCH with FASTBAC attached.

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8. Summary

A number of critical factors emerged for both dismounted and mounted applications of the prototype maxillofacial protection systems examined during this assessment.

8.1 Part I – Dismounted Compatibility Assessment Summary

For dismounted small arms applications, the front and side spatial breadth of some of the larger form factor maxillofacial protection systems was generally determined to have a negative impact on the ability to successfully acquire and maintain a high-quality sight picture. This negative interaction between the device and some weapon/sighting systems was minimized, however, when factors such as spacing between the front of the maxillofacial system and the helmet brim were large enough to accommodate, for example, the rubberized eyecup feature on the LTWS and MTWS. For most other weapon, sighting system, and firing position combinations, a large maxillofacial form factor featuring extensive front and side spatial breadth forced shooters into awkward head and neck postures that prevented proper sighting or degraded the ability to maintain a target sight picture over time once a sight picture was achieved. With some weapon systems, however, this negative effect did not manifest itself due to design accommodations such as deep curvature of the buttstock (e.g., M240B).

8.2 Part II – Mounted Compatibility Assessment Summary

When attempting to acquire a target sight picture while mounted in either the Stryker Combat Vehicle or Bradley Fighting Vehicle, wearing maxillofacial protection systems generally produced a negative impact on the sighting of the GPS and GAS given the close proximity between the eye and sight that is required to obtain a proper sight picture and the eye-sighting

system standoff that is produced when they are worn. The GTS does not require such close standoff proximity with the eye, so wearing a maxillofacial protection system did not negatively influence the process of obtaining a proper sight picture. Wearing a CVCH without an accompanying maxillofacial protection system generally did not impact the sighting process. While attachment brackets that remained affixed to the CVCH interfered at times with flush positioning of the head and face against GPS/GAS brow pads or other protruding sighting system features, this interference typically did not approach a level that prevented the successful acquisition of a sight picture. Additionally, tilting the helmet backward effectively mitigated any such interference that was caused.

8.3 Overall Summary

Ideally, proper sighting of either small arms weapons systems or vehicle-mounted sighting systems is best accomplished without maxillofacial protection, with any medium placed between the operator's face and the weapon/sighting system adversely affecting a natural cheek-to-weapon stock weld or eye-to-sighting system effective distance threshold. However, effective sighting may be accomplished while wearing maxillofacial protection as long as the system does not force the operator far beyond the spatial parameters dictated by the interaction between head, face, eye, sighting system, and weapon firing position. These constraints of human-system interaction are best maintained when the protection system adopts a form factor that minimally changes the natural spatial dimensions and curvatures of the face and head. Minor adjustments in posture and position will, however, allow for effective use of maxillofacial protection systems that minimally change these parameters.

Based on the findings described here, follow-on prototypes that incorporate functional design changes will be developed and quantitatively assessed with greater empirical rigor. Working with NSRDEC, the Dismounted Warrior Branch will build on this initial rapid assessment with a series of formal assessments that incorporate additional firing postures, live-fire scenarios, and marksmanship metrics (dismounted assessment), as well as combat vehicle-specific operators as expert research participants (mounted assessment), all of which will incorporate anthropometric measurements to improve the specificity with which design attributes may be associated with functional capability across prototypes. This series of assessments will culminate in improved helmet and maxillofacial protection systems that have been driven at the earliest stages by human factors and ergonomic concerns, ultimately to be employed by U.S. Army Soldiers within both dismounted and mounted tactical scenarios.

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